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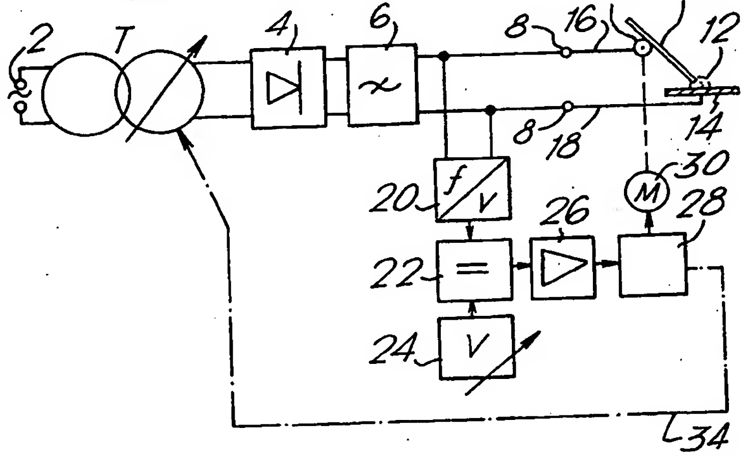
(54) **Controlling gas-shielded consumable electrode arc welding in dip transfer mode**

(57) Arc welding using a gas shielded consumable electrode in the dip transfer mode is controlled by sensing the dip transfer frequency by sensing frequency of current peaks, voltage dips (as shown) or, optically, arc light and adjusting either the speed at which the electrode is fed towards the molten weld pool or the level of arc current and/or voltage to obtain substantially maximum dip transfer frequency and, hence, optimum welding conditions. The sensed dip transfer frequency may be used to provide audible and/or visual signals for parameter control by an operator, or, as shown, used in an automatic retroactive control.

FIG. 2.



The drawings originally filed were informal and the print here reproduced is taken from a later filed formal copy.

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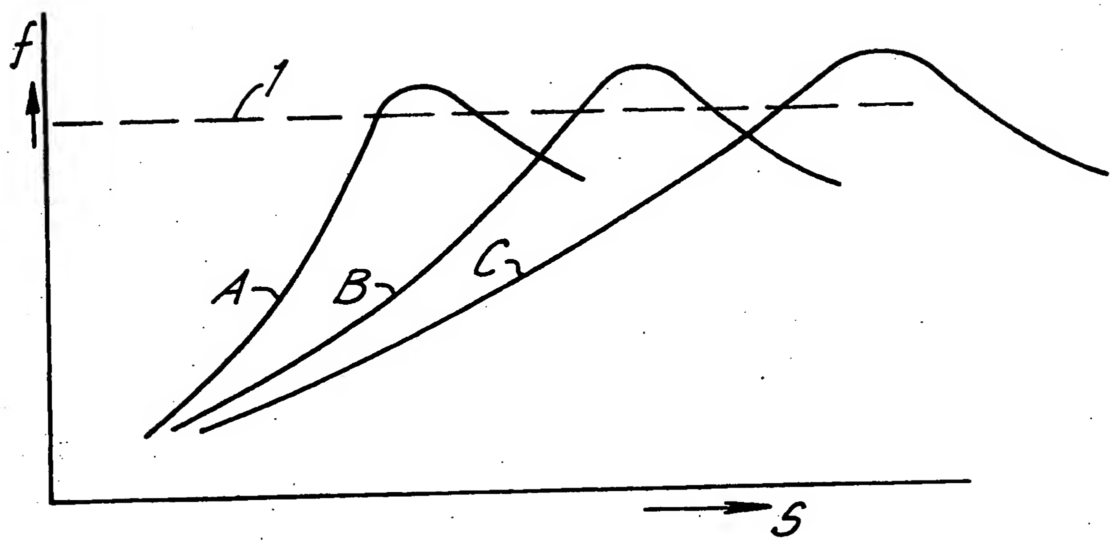
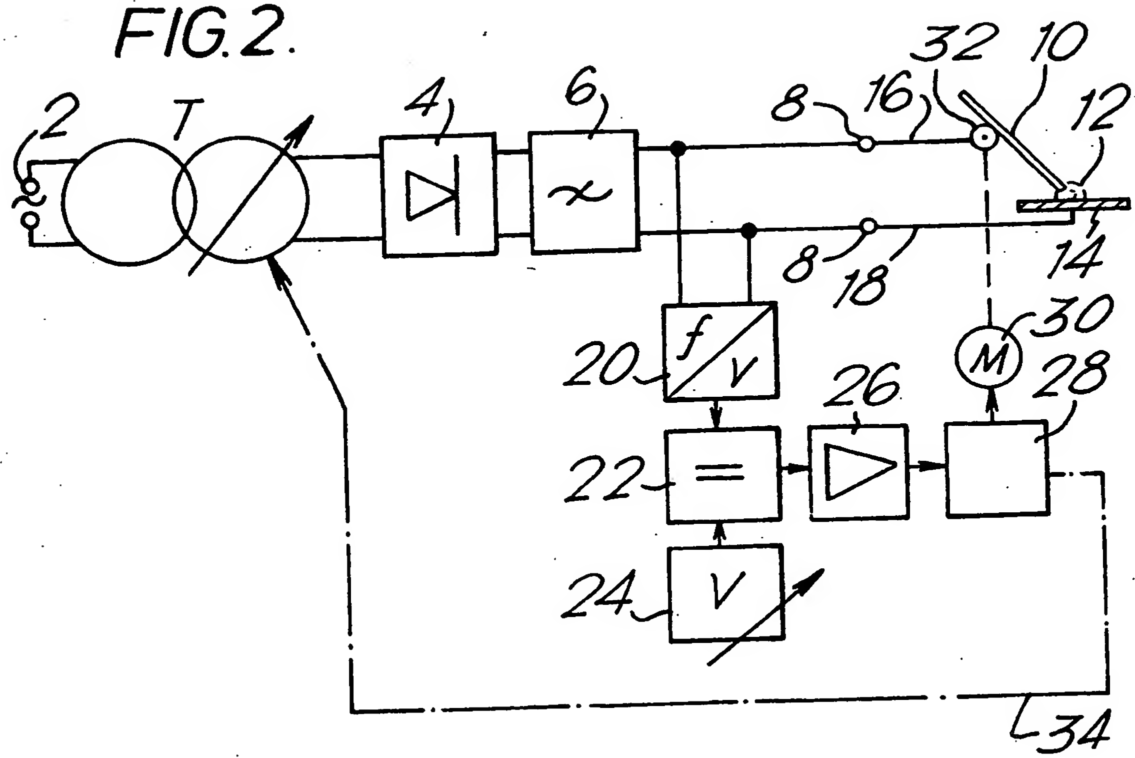


FIG.1.

FIG.2.



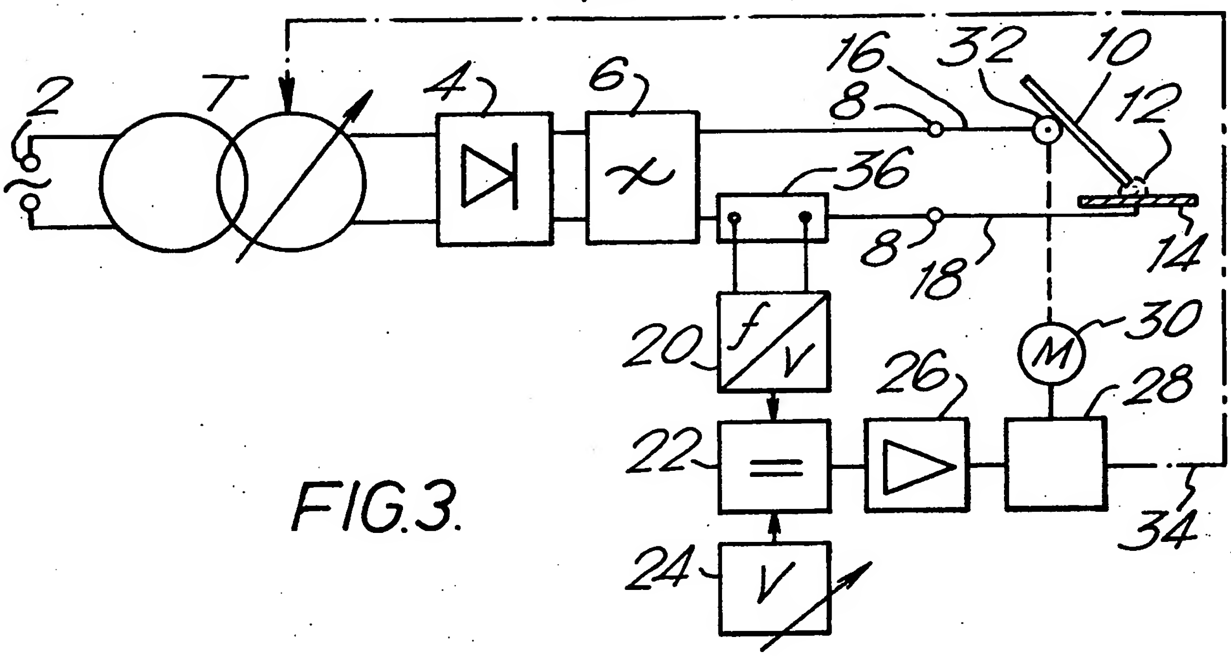


FIG.3.

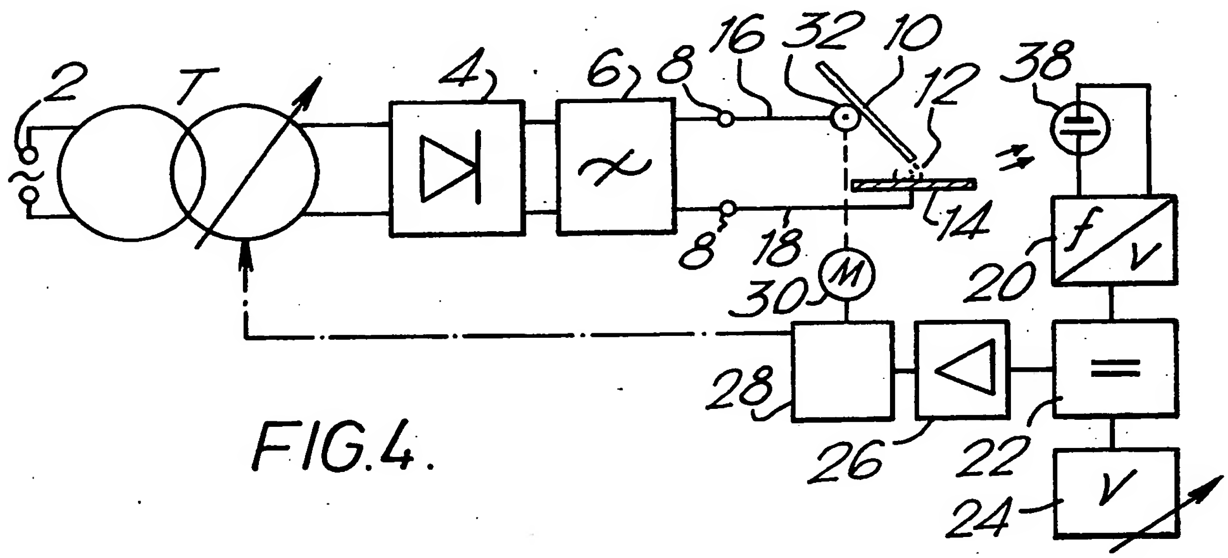


FIG.4.

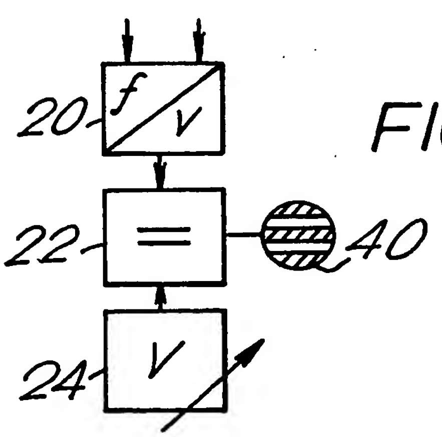


FIG.5.

SPECIFICATION

Arc welding

The present invention relates to methods of and power sources for controlling the weld condition during an arc welding operation using a gas-shielded consumable electrode in the dip transfer mode.

In the dip transfer mode of welding, sometimes refered to as 'short-arc welding', metal is transferred to the work when the molten tip of the electrode contacts the molten puddle. The end of the electrode becomes fused by the heat of the arc and by the Joule heat released in it by the passage of a welding current along the electrode. As the electrode is fed towards the molten pool, the droplet of fused electrode dips into the molten pool and thus momentarily short circuits the arc. Surface tension forces very quickly draw the droplet into the molten pool leaving the unfused end of the electrode spaced from the surface of the molten pool thus allowing the welding arc to be re-established. The molten droplet short circuits the arc an average of 100 times per second and at rates lower and much higher than this. Metal is transferred with each short circuit rather than across the arc as in spray arc welding for example.

These relatively high frequency short circuits of the welding power source give rise to a series of low voltage dips, and high current peaks in the voltage and current.

For a given shielding gas and an electrode of known cross-sectional area, the dip frequency varies as a function of the quality of the weld condition (primarily set by the relationship of output volts and amperes, and the rate of rise of current, as determined by the inductance of the output circuit). In practice, the optimum weld condition is when the dip frequency is at, or just below, its maximum. This optimum dip frequency is approximately constant irrespective of the current setting on the power source. It follows that if the maximum dip frequency can be detected and controlled, then the optimum weld conditions can be also be controlled.

According to one aspect of the present invention, a method of controlling the weld condition during an arc welding operation using a gas-shielded consumable electrode in the dip transfer mode comprises the steps of:

(a) detecting the dip transfer frequency; and

(b) generating a signal in response to the dip transfer frequency detected for controlling either the speed at which the consumable electrode is fed towards the molten weld pool or the level of arc voltage.

According to a further aspect of the present invention, a power source for controlling the weld condition during an arc welding operating using a gas-shielded consumable electrode in the dip transfer mode comprises means for detecting the dip transfer frequency and means for generating a signal corresponding to the dip transfer frequency detected for controlling either the speed at which the consumable electrode is fed towards the molten weld pool or the level of arc voltage.

Embodiments of the present invention will now be described by way of example, reference being made to the Figures of the accompanying diagrammatic drawings in which:

Figure 1 is a series of graphs of dip transfer frequency against wire feed speed for different levels of output voltage;

Figure 2 is a block diagram of a power source of the present invention;

Figure 3 is a block diagram of a power source similar to that shown in Figure 2 but responsive to welding current rather than welding voltage.

Figure 4 is a diagram of a third embodiment of power source which is responsive to light emitted by a welding arc; and

Figure 5 is a block diagram of means for signalling when the desired dip frequency has been attained.

The graph shown in Figure 1 is of observed transfer frequency (f) against wire feed speed (S) for a specific electrode diameter and shielding gas. The three curves (a), (b) and (c) are for different output voltage settings. Curve (a), for example, is for a low value of output voltage. As the welding conditions produced by the power source approach the optimum, the detected dip transfer frequency increases until it reaches a maximum value which is specific to that electrode and shielding gas; optimum welding conditions are reached at or just below this maximum. Similarly, this applies to curves (b) and (c) which are progressively higher output voltage settings but which have optimum welding conditions at dip transfer frequencies which are the same as or only slightly higher than that for voltage (a) and are represented by the horizonal broken line (1) passing through the peaks of the curves.

The power sources shown in Figures 2 and 3 incorporate a transformer T intended to be supplied with mains electricity applied across input terminals 2. The transformer is adapted to deliver a low voltage, high current supply which, after rectification in a rectifier 4 and smoothing in a filter 6, is fed to output terminals 8. Output terminals 8 are intended in use to be connected by cables 16, 18 respectively to a consumable electrode 10 and a workpiece 14.

As shown in Figures 2 and 3, variations in the arc voltage or current are detected between the filter 6 and the output terminals 8.

In the power source shown in Figure 2 tappings across the cables 16, 18 are connected to a transducer 20 designed to change the voltage variations at the dip transfer frequency detected in the arc into a corresponding voltage. The transducer 20 feeds its output to a comparator 22 having as a second input a signal from a variable voltage source 24 acting as a reference. The source 24 normally produces an adjustable signal corresponding to a desired frequency of dip transfer. The comparator 22 is designed to supply this "difference signal" to an amplifier 26. The amplified signal is fed to a voltage control circuit 28 which may either energise a motor 30, driving electrode feed rollers 32 engaging electrode 10, so that the electrode is driven towards the workpiece 14 (and molten pool) at a speed dictated by motor 30, or adjust the output voltage of the

transformer T by a connection indicated by a line 34.

The variable voltage source 24 is provided as a reference signal, which can be set to a level corresponding to the required frequency of dips of the consumable electrode to produce a good welding condition for the selected electrode diameter and material and shielding gas. As explained, this reference level once set, remains constant in the majority of cases regardless of welding current required. However, in the case of power sources employing saturating chokes in the output circuit, this reference level may have to be lowered when using low welding currents in order to create a satisfactory weld.

When the optimum dip frequency is obtained in the arc by one method of control or the other, there is no difference signal produced by comparator 22 and thus the welding condition settles to a constantly good condition.

An alternative method of sensing the welding condition is to sense when the dip frequency reaches a maximum rather than a preset level using for example, a peak follower circuit and at this point, the condition would be held stable by the resultant motor speed or output voltage controller.

In the remaining Figures, those components common to the power source shown in Figures 2 and 3 have been given the same references.

The main difference between the power sources Figures 2 and 3 is that in the latter the dip frequency is detected by variations in the current developed across a resistor 36 inserted in welding cable 18 and traversed by the welding current.

Figure 4 shows an alternative method of sensing the dip frequency. Instead of sensing either voltage dips or current peaks as described earlier and indicated in Figures 2 and 3, the light emitted from the welding arc can be used. When the wire actually dips into the molten pool, the arc is extinguished and the light goes out. An optical sensor, for example a photo-voltaic cell 38 can, with suitable filtering and focasing of the light, be used to provide a pulse each time the light is extinguished. This electrical signal would be identical to the dip signals of the previous embodiments and could therefore be used with the control circuits already discussed.

Figure 5 is a further modification in which the dip frequency of the arc is sensed, converted to a voltage signal and compared with a reference signal just as previously explained. However, the comparison of the two signals is not done by a differential amplifier but by a pure level comparator 22. When the welding condition thus produced is the required number of dips, that is, a good welding condition has been reached, the comparitor 22 changes stage, thus triggering an indicator 40 which gives an audible or visual signal or both when the desired dip frequency is attained. This method provides a simple and cheap method whereby the operator can tune in the current and/or voltage to achieve a satisfactory condition for any size plate to be welded.

An alternative to this could be to make the complete unit portable, and remote from the welding power source. By using batteries to power the device and an optical sensor to detect to dips the whole could be produced in a small pocket size package. This could be particularly useful where multi-unit automatic operations were concerned enabling the operator to set up his condition quickly and easily for each unit and be able to check that the condition is being maintained. Conversely, of course, the invention could be used to provide a warding when a bad welding condition was being produced. Either of these could result in the welder carrying a small buzzer or other indicator clipped to his clothes. The buzzer could pick up or receive signals indicating the detected dip frequency. The buzzer could either generate sound when the dip frequency was close to its optimum or at all other times so that the welder could operate the power source controls until he either obtained the buzz or silenced it, the welding conditions in either case being at or near the optimum.

CLAIMS

1. A method of controlling the weld condition during an arc welding operating using a gas-shielded consumable electrode in the dip transfer mode comprising the steps of detecting the dip transfer frequency and generating a signal in response to the dip transfer frequency detected for controlling either the speed at which the consumable electrode is fed towards the molten weld pool or the level of arc voltage.

2. A method as claimed in claim 1, in which the dip transfer frequency is detected as arc voltage dips.

3. A method as claimed in claim 1, in which the dip transfer frequency detected as arc current peaks.

4. A method as claimed in claim 1, in which the dip transfer frequency is detected optically from the welding arc.

5. A method as claimed in any one of the previous claims, in which the signal generated in response to the dip transfer frequency detected is compared to a reference signal indicative of the desired dip frequency for a good welding condition, any differences generating a further signal for controlling either the speed at which the consumable electrode is fed towards the molten weld pool or the level of arc voltage until the differences are eliminated.

6. A power source for controlling the weld condition during an arc welding operation using a gas shielded consumable electrode in the dip transfer mode comprising means for detecting the dip transfer frequency, and means for generating a signal corresponding to the dip transfer frequency detected for controlling either the speed at which the consumable electrode is fed towards the molten weld pool or the level of arc voltage.

7. A power source as claimed in claim 6, in which the signal corresponding to the dip transfer frequency detected is compared with a reference signal indicative of the desired dip frequency for a good welding condition, means for generating a further signal corresponding to the differences between the reference signal and the detected signal, said further signal controlling either the speed at which the

consumable electrode is fed towards the molten weld pool or the level of arc voltage.

8. A power source as claimed in claim 6 or 7, in which an audible or visual means is provided which when the desired dip frequency is achieved is actuated.

9. A power source as claimed in any one of claims 6 to 8 in which the reference signal is adjustable to take into account differences in electrode size, composition and various shielding gases used.

10. A method of controlling the welding condition during an arc welding operation using a gas shielded consumable electrode in the dip transfer mode. substantially as hereinbefore described with reference to the Figures of the accompanying drawings.

11. A power source for controlling the welding condition during an arc welding operation using a gas-shielded consumable electrode in the dip transfer mode constructed and arranged substantially as hereinbefore described with reference to and as illustrated in the Figures of the accompanying drawings.

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